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ABSTRACT

The Radio Mathematics Project was established to design, implement, and evaluate a prototype system of teaching elementary mathematics using radio as the major medium of instruction. Daily mathematics lessons were presented to first and second graders in rural and urban primary schools in Nicaragua. Lessons had a radio and a postbroadcast portion, each about 30 minutes long. Radio lessons were constructed from segments of instructional material and entertainment activities, both of which required a high level of active response from the children. It was found that first grade children learned new mathematical concepts and skills from radio instruction supplemented by a student worksheet. Children remained attentive and responsive for the radio lesson, provided they had the opportunity to respond frequently. Children were able to respond at the rate of three to four times a minute. They enjoyed the instructional segments of the lessons, and the entertainment segments were not necessary to maintain the children's attention. Test results indicated that children in radio classrooms performed better than children in traditional classrooms on all topics taught by radio. (Author/CH)

Third Annual Report
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APPLICATION OF RADIO TO TEACHING ELEMENTARY MATHEMATICS IN A DEVELOPING COUNTRY

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ABSTRACT

The Radio Mathematics Project was established to design, implement, and evaluate a prototype system of teaching elementary mathematics using radio as the major medium of instruction. The project, working in rural and urban primary schools in Nicaragua, presents daily mathematics lessons in first- and second-grade classrooms. A lesson has a radio and a postbroadcast portion, each about 30 minutes in length. Radio lessons are constructed from segments of instructional material and entertainment activities, both of which require a high level of active responses from the children. In its work thus far, the project has found (a) that first-grade children can learn new mathematical concepts and skills from instruction given by radio and supplemented by a student worksheet, (b) that children remain attentive and responsive for a half-hour radio lesson, provided they have the opportunity to respond frequently, and (c) children are able to respond at the high rate of three to four times a minute. The children enjoy the instructional segments of the project lessons. Although they provide a change of pace, the entertainment segments are not necessary for maintaining the children's attention. Test results indicate that children in radio classrooms perform better than children in traditional classrooms on all topics taught by the radio.

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INTRODUCTION

The Radio Mathematics Project was established to design, implement, and evaluate a prototype system of teaching elementary mathematics, using radio as the major medium of instruction. Since June 1974 the Institute for Mathematical Studies in the Social Sciences of Stanford University (funded by the United States Agency for International Development) and the Government of Nicaragua have been collaborating on the development of such an instructional program for use in the primary schools of Nicaragua. In this report we summarize the work of the year ending June 30, 1976, and describe plans for the final year of the contract, which ends June 30, 1977.

The goals of the Radio Mathematics Project, as set forth in the contract between AID and the Institute, are (a) to develop and test a cost-effective prototype system of radio mathematics instruction for elementary grades in a less developed country that could, with minor adaptations and translation, be used in many countries, (b) to develop a methodology for producing radio instructional materials based upon the rapid and specific reporting of student responses, and (c) to begin a program of research on major variables affecting learning through radio. The project was also charged with building capabilities in an appropriate host-country institution to continue or even expand the work of the project with minimal further assistance from external experts. In the course of this report we will discuss progress towards each of these goals.

The project opened its offices in Nicaragua in June 1974. The remainder of 1974 was spent recruiting and training staff, developing and pilot-testing a set of six radio lessons, writing and administering an achievement test to approximately 1,250 first-grade students, and observing traditional first-grade and second-grade classrooms. This work is described in the annual report for 1975 (Searle, Friend, & Suppes, 1975) and in a forthcoming book (Searle, Friend, & Suppes, in press). Experimental work in the classrooms began with the start of the new school year in February 1975. The project produced daily mathematics lessons that were used by teachers in 16 classrooms. The recorded portion of each lesson was presented by tape recorder, and each lesson was accompanied by a student worksheet. The project lessons were observed daily by members of the staff and completed student worksheets served as a source of performance data.

The present reporting period covers the second half of the 1975 school year and the first half of the 1976 school year. A full report on the activities of 1975 is in press at the time of this writing (Searle, Friend, & Suppes, in press); that work is summarized briefly in this report. The project plans to publish a similar volume describing the activities and results for the 1976 school year.

PROJECT CALENDAR

July 1, 1975 to June 30, 1976

July 1	Middle of 1975 school year Lesson 71, Grade 1, presented in experimental classrooms
August 6	Weekly paper-and-pencil tests initiated
September - November	Mental arithmetic tests administered
October 27 - November 14	Posttests administered to Grades 1 and 2 Teacher questionnaires distributed Teacher interviews conducted
November 21	End of school year Lesson 150, Grade 1, presented in experimental classrooms
January 14	Research Committee meeting, Stanford
February 9-13	First teacher-training sessions held
February 16	8:30 a.m. Lesson 1, Grade 1 9:45 a.m. Lesson 1, Grade 2 broadcast over Radio Nacional
February 23 - March 29	Pretests administered in Grade 1
March	Teacher questionnaires distributed
March 15-19	Second teacher-training sessions held
March 3 - April 2	Pretests administered in Grade 2
March 12 - April 7	Pretests administered in Grade 3
April 2-7	Pretests administered in Grade 4
June 30	Middle of 1976 school year Lesson 89, Grades 1 and 2, broadcast over Radio Nacional

I. THE 1975 OPERATIONAL YEAR

A. Instructional Program

During 1975, 165 first-grade lessons were produced, each designed to occupy approximately one hour of class time. With a few exceptions, each lesson consisted of a recorded portion, i.e., the radio lesson, and a postbroadcast portion, i.e., activities directed by the teacher. (The radio lesson was omitted from some early lessons.) The radio lessons, which were presented daily by tape recorder, occupied from 15 to 25 minutes, increasing in length as the year progressed. Student worksheets accompanied most lessons; completed worksheets were collected from all classrooms and were used as a source of information about student performance levels.

Curriculum development for both the radio and postbroadcast portions of the lesson was guided by the formulation of a set of performance objectives for the first-grade mathematics program. The objectives were developed from the primary-school curriculum guide prepared by the Nicaraguan Ministry of Education and reflect the goals set by the Ministry for the Nicaraguan educational system. Searle, Friend, and Suppes (in press) describe in detail the structure of the radio lessons, the organization of the curriculum for presentation by radio, and the instructional methods used.

B. Operations in Schools

The project worked in 16 primary classrooms in the Department of Masaya, reaching approximately 500 students at the beginning of the school year. (This number decreased by almost half during the course of the year, as students dropped out of school.) Experimental classrooms were distributed among rural, municipal, and urban schools in approximately equal numbers.

Participating teachers were selected to be representative of differences in training and experience. They were chosen by the project staff in consulation with the school inspector and his assistants. Eight teacher-training sessions were held, three of them before the school year began. Teachers responded to a questionnaire before and after using the radio instructional program and were interviewed at the end of the school year.

A regular schedule of classroom visits was maintained. The mathematics lesson was observed daily in six, and once a week in five, experimental classrooms. At the beginning of the year the remaining five classrooms were not observed so that we could find out what troubles teachers had using the program on their own. They had some opportunity for communication with staff members because worksheets

and teacher's guides were delivered regularly. They seemed to have little difficulty and for the second half of the the year these classes were included in the observation schedule.

In April, six additional classrooms in the neighboring department of Granada were provided with radio lessons. These classes were supervised by the School Inspector for Granada and had no direct contact with the project staff. Materials were delivered to the Inspector's office for further distribution and teachers were trained by the Inspector, using suggestions and materials provided by the project. The Granada classes were added to test the feasibility of using project materials without direct supervision.

C. Data Collection Procedures

Several methods of collecting data were used to support the curriculum development work of the project. Classroom observers provided a daily record of the use of lessons in the classroom. They reported on the pacing of lessons and exercises, errors in the recording or the worksheet, the level of responsiveness and interest shown by the children and the appropriateness of presentations. During the year several types of instruments were used to record observations. The most successful of these identified the beginning of each segment and, for each segment, provided a space for the observer to comment on a standard set of questions and special questions posed by the curriculum developer or the script writer. All members of the professional staff, including the curriculum developers, the script writers, and the radio producer-director, were required to visit classrooms on a regular basis.

Further information about student performance was obtained from the analysis of student worksheets. Although the children did not complete the worksheets independently (there was much cooperation between the children and help from the teachers), the results nevertheless provided much information about strengths and weaknesses of the curriculum. Near the end of the year the project supplemented the analysis of worksheet data by administering paper-and-pencil tests weekly in selected classrooms.

D. Achievement Testing Program

There are no mathematics achievement tests available for use in Nicaragua. The Ministry of Education does not have a testing program and no tests have been standardized using the Nicaraguan population. ~~The~~ project therefore either had to construct its own tests or find them elsewhere. The former alternative was adopted for all but the first-grade pretest. All tests developed by the project used tape-recorded instructions. Questions were designed to require either free-response or multiple-choice responses.

First-grade pretest. Because there was not enough time to develop a first-grade pretest before school opened, the Spanish version

of the mathematics subtest of the Test of Basic Experiences (TOBE), Level K, published by CTB/McGraw-Hill, was adapted for use in Nicaragua. The Spanish version was written for Spanish-speaking children in the United States and required substantial revision for use in Nicaragua. The changes are described by Searle et al. (1975). The TOBE was administered to 533 students in the 16 experimental classrooms in early March, two weeks after school opened, and to 267 students in nine traditional classrooms four weeks later.

First-grade posttest. The posttest was designed using a multiple matrix-sampling design. Searle, Friend and Suppes (in press) discuss the construction of the test, which assessed performance on the objectives defined for the radio instructional program and on additional topics taught in traditional classrooms. Each of the four student test forms contained 22 items and data were collected on a total of 88 items. The test was administered in November to 323 students in experimental classrooms, 195 students in traditional classrooms, and 242 students in the Granada classrooms.

Second-grade posttest. In November an achievement test was given in the second grade to assess year-end performance levels. The test was similar in structure to the first-grade achievement test. It contained 125 items, 25 of which were given to each child. The test was taken by 463 students from 21 classrooms selected at random from urban and rural schools in Masaya. Items tested 28 objectives of the second-grade curriculum described in the Nicaraguan curriculum guide. The results of this test were used to guide development of the second-grade radio curriculum.

E. Teacher Questionnaires and Interviews

In 1974 a questionnaire was designed to investigate teachers' attitudes towards mathematics, mathematics teaching, teaching as a profession, and the use of instructional radio. The questionnaire contained 50 items that asked for agreement (or disagreement) on a five-point scale and four incomplete-sentence items. Teachers were also asked to supply information on their educational background and experience. The questionnaire was administered to 44 first-grade teachers in November 1974. In 1975 it was substantially revised, after the initial results identified some ambiguous items. As part of the revision process, small groups of teachers were asked to respond to selected items and then discuss their responses with a staff member. In this way we discovered that statements phrased in the negative were often responded to as though they were phrased positively. The revised questionnaire had 46 agree-disagree items and three incomplete sentences. At the end of 1975 it was sent to 32 first-grade teachers and all but one questionnaire was returned.

The questionnaire was designed as an instrument appropriate for assessing attitudes of large numbers of teachers of both experimental and traditional classes. In order to gather more specific information

about the experimental classrooms, the staff interviewed participating teachers. The teachers were assured that the purpose of the interview was to obtain their opinions about ways to improve the project and most of the teachers agreed to let the staff member tape-record the interview. The interview schedule was structured, but the interviewer was allowed to ask additional questions when he thought it would clarify a teacher's response. Interviews were conducted with all 17 of the teachers in Masaya and four of the six teachers in Granada.

F. Results

Although the project lessons retained their basic structure and format throughout the experimental year, many changes were made. Radio lessons were lengthened, more time was devoted to instruction and less to entertainment, children were asked to respond more frequently, and stories were replaced by additional songs, games, jokes, and riddles. The changes were stimulated by classroom observations and the examination of performance data from student worksheets and tests. Searle, Friend, and Suppes (in press) discuss the sources of data and their impact on the design of lessons.

Among the most significant findings about the capabilities of first-grade children were the following:

1. Children are able to learn new concepts and skills from instruction given by radio and supplemented by a worksheet.

2. Children remain attentive and responsive for a half-hour radio lesson, provided they have the opportunity to respond frequently.

3. Children are able to respond at the high rate of three to four times a minute.

4. Children are able, with adequate directions, to keep their place on a worksheet that has up to 30 different displays or locations for responding.

5. Children can work with concrete materials, such as bottle caps, during a radio lesson.

6. Children enjoy the instructional portions of the lessons. The entertainment portions, although they provide a change of pace, are not necessary for maintaining the children's attention.

During the experimental work of 1974 and 1975 the project developed a successful lesson format that had two parts, the radio portion and the postbroadcast portion. The main characteristics of the radio portion are the following:

1. A radio lesson consists of segments, and each segment is independent of the others. Each segment has as its main purpose either instruction or entertainment.

2. All instructional segments require active responses from the students. Most entertainment segments similarly require active responses.

3. A high response rate, averaging three responses per minute, is maintained throughout the lesson.

4. The instructional segments of a lesson are drawn from different topics and require different types of responses.

5. All instructional segments consist of exercises.

6. The correct answer is given for each exercise after the children have had the opportunity to respond.

7. Transitions between segments are short, simple, and often nonverbal.

The postbroadcast portion of the lesson is under the direction of the teacher. It usually contains instructional material from topics that have already been taught by the radio. The teacher is asked to provide activities to help children understand and practice what has already been learned. Suggestions and directions are provided in a short teacher's guide prepared to accompany each lesson.

At the end of the school year the teachers in experimental classrooms were interviewed concerning their participation in the project. Fifty-eight percent of the teachers said they enjoyed teaching mathematics more with radio than without, and 73% felt that the children learned more this year than last year. The majority (59%) thought their work load was reduced by using radio lessons. The teachers were asked what they thought was the major benefit of working with the project. Among the responses were (a) children worked better (32%), (b) use of worksheets and materials was helpful (28%), (c) teachers acquired new teaching experiences (20%), (d) teachers observed better teaching techniques (16%), and (e) lesson presentations were clearer (4%). When asked to cite the major difficulty they experienced, 42% said there were no problems. The remainder mentioned problems, but the responses were quite diversified; for example: (a) adaptation to a new method was difficult, (b) some mathematics lessons were lost because of failure of the tape recorder, (c) some of the worksheets were not printed correctly, (d) the slow children had difficulties, (e) the teacher could not attend the training sessions, (f) not enough mathematics was covered, (g) absenteeism presented problems, and (h) the teacher had to explain parts of some lessons to the children. Ninety-two percent

of the teachers said they would recommend the project lessons to other teachers.

The teachers were asked several questions about how others in the school and the community felt about the project's lessons. They reported that many questions were asked by other teachers, who expressed curiosity about all aspects of the project and expressed many doubts about teaching by radio. Among the reasons given for skepticism were: (a) children cannot learn from a recording, (b) there are too many games--too few individual activities, (c) lessons cannot be repeated, and (d) they require too much work for the teacher. There were some indications that the teachers, feeling freer to attribute these opinions to others, were expressing some of their own doubts. As with the direct criticisms cited above, there was little consensus about these negative reactions.

Almost all the teachers (95%) reported having talked with at least some of the parents about the radio lessons. About a third of the teachers said they met with parents in groups, others saw parents individually. According to the teachers, the response of the parents was overwhelmingly positive. The major concern expressed by the parents was the lack of homework in mathematics, and most teachers (90%) agreed that children should have homework. In addition, the teachers thought the project should make more effort to communicate directly with the parents through meetings (38%), radio broadcasts (25%), a bulletin for parents (21%), and other means.

The teachers were asked for which ability group in their class were the lessons most adequate. Their replies were: top, 22%; middle, 61%; bottom, 17%. Approximately two-thirds thought that failure of the slow group to understand was a more significant problem than that lessons were not sufficiently advanced for the fast group.

The teachers had several suggestions for improving the program. They thought more materials should be used during the broadcast, that more varied activities should be suggested for the postbroadcast period, that multiplication and division should be included in the curriculum, and that the project staff should help them grade the children.

The success of the instructional program was assessed by examining how well students met the performance objectives set for them by the project. The process of defining performance objectives and developing test items to measure attainment of these objectives is discussed by Searle, Friend, and Suppes (in press). The project defined two types of objectives, minimal and advanced. Minimal objectives are those objectives for which the project expected performance levels of 75% to 85% correct; performance levels for advanced objectives were expected to be lower. Test scores summarized by strand are shown in Table 1. On the average, performance levels were within expectations for fractions, addition, and applications, slightly low for numeration, and quite low for subtraction.

Table 1

Attainment of Minimal and Advanced Objectives
by First-grade Experimental Students

Strand	Minimal objectives: Number of items	Minimal objectives: Mean percentage correct	Advanced objectives: Number of items	Advanced objectives: Mean percentage correct
Numeration	12	74.3	10	63.1
Fractions	4	76.9		
Addition	19	76.8		
Subtraction	12	62.6		
Measurement	1	94.3		
Applications	12	83.6	3	61.4

(Measurement, with only a single item, was not adequately tested.) Thus, for most topics, students performed adequately.

For comparison, the scores for students in nine traditional classrooms are presented in Table 2. (The topics tested are all part of the traditional first-grade curriculum.) For none of the strands did performance meet the project criterion of 75% correct and, except for numeration and applications, the mean percentage correct for traditional students was about 20 points lower than for experimental students. A more detailed picture of the strengths and weaknesses of students in both groups is presented by Searle, Friend, and Suppes (in press).

The results of the project pretest leave open the question of whether the experimental students and those in the nine selected traditional classrooms were similar in mathematics ability. The students in experimental classrooms (which were not selected at random) were tested during the third week of school; those in the traditional classrooms were tested four weeks later. The mean score on the 28-item test was 19.9 for the experimental students and 21.2 for the traditional students. The difference in favor of the traditional students is statistically significant. It seems likely that the higher score of the traditional group reflects the later testing date. It also seems reasonable to suppose that, if there is a true difference between groups, it is in favor of the traditional students, but we have no evidence for such a conclusion. With these caveats about the comparability of groups, we present in Table 3 the mean item scores for three groups, experimental, traditional, and Granada students. All 88 items were used

Table 2

Attainment of Minimal and Advanced Objectives
by First-grade Traditional Students

Strand	Minimal objectives: Number of items	Minimal objectives: Mean percentage correct	Advanced objectives: Number of items	Advanced objectives: Mean percentage correct
Numeration	12	67.8	10	50.3
Fractions	4	53.8		
Addition	19	58.6		
Subtraction	12	43.5		
Measurement	1	72.5		
Applications	12	70.4	3	63.9

Table 3

Posttest Performance--Item Scores

Group	n	Percentage correct: Mean	Percentage correct: Standard deviation
Experimental	88	67.3	23.8
Traditional	88	55.5	21.4
Granada	88	68.4	25.1

to calculate mean scores (only 73 of the items tested project objectives and were therefore included in Tables 1 and 2.) The experimental group and the Granada group (also using radio lessons but not part of the initial experiment) achieved approximately the same mean item scores, while the traditional group was significantly lower.

G. Recommendations

The major recommendations resulting from the work of the first year concern the worksheet and methods for collecting performance data. These issues are related. Worksheets were adopted as a component of the lessons for two reasons, because they provided a source of data about student performance and because the staff thought it was essential that some printed material be available for student use during the lessons. During the year, the worksheet was superseded by paper-and-pencil tests as the major source of performance data. The tests were more successful because they were administered under controlled conditions, thereby reducing copying, and because items could be chosen with more freedom than during a lesson, allowing the collection of more useful data. It also became clear that teachers could be asked to write material on the blackboard and that students could be asked to draw simple pictures. Thus, it seems likely that a successful first-grade course could be constructed without worksheets. Because the worksheets are an expensive component of the program, the project chose to eliminate them from all further work and strongly recommends that the first-grade program be revised without worksheets.

II. THE 1976 OPERATIONAL YEAR

During 1976 the project is presenting mathematics lessons in both first-grade and second-grade classrooms. Lessons for both grades are broadcast using the facilities of Radio Nacional. The project has expanded its operations and is now working in three departments, Masaya, Granada, and Carazo.

A. Instructional Program

A revised version of the 1975 first-grade program is being used in 1976. Eight new radio lessons were produced to complete the sequence of early lessons, and the entire set will be extended to include 165 recorded lessons. New material is being added to those lessons that were shorter than 25 minutes. In addition, some segments are being revised, either to change the content or to improve the instructions. Approximately 15% of the instructional material is being changed in this way. The changes in lesson material and lesson length have, thus far, required recording changes in over 60% of the scripts. The teacher's guides were felt to be a weak part of the 1975 lesson materials and are being completely rewritten. Student worksheets are being changed only where pictures were found to be confusing or where errors were made.

The first version of the second-grade lessons is being developed during 1976. The lessons are not accompanied by worksheets; rather, teachers are asked to copy exercises from the teacher's guide onto the blackboard and, for written work, the children use their notebooks. The second-grade radio lessons have the following types of exercises.

1. Oral exercises and word problems.
2. Exercises that are copied from the blackboard into the notebooks before transmission starts and used later.
3. Exercises that refer to illustrations on the blackboard.
4. Exercises that use the notebooks, but not the blackboard.
5. Exercises that use both the notebooks and the blackboard.
6. Exercises that use individual materials.

There is usually a transition segment that contains exercises that the children complete after the recorded lesson. There are several post-broadcast segments and, on occasion, assigned homework. The program always starts with oral exercises to allow the teacher time to write the required material on the blackboard, if she has not already completed this task.

The second-grade lessons are based on a more elaborate curriculum structure than that used during 1975. First, the curriculum material appropriate for second grade was organized into 30 strands and each strand was further subdivided into instructional classes of

exercises. Second, the classes were graphed to display the prerequisite structure and, based on this graph, a master teaching plan was constructed that assigned to each class an initial-teaching week. All of the second-grade instructional material in the Ministry curriculum guide was included in the master teaching plan. (In 1975, the decision was made at the beginning of the year to restrict the curriculum to fewer topics than those mandated by the guide. This decision was criticized by both teachers and supervisors.) The method for using feedback to influence curriculum development (described below) allows for modification of the master teaching plan. If some topics must be postponed, the second-grade lessons may not cover all of the material in the guide, but the decision to postpone material will be made only if indicated by test results.

B. Operations in the Schools

Project lessons for 1976 were initiated on February 16, shortly after the opening of the school year. Second-grade lessons were broadcast at 8:30 a.m. and first-grade lessons at 9:45 a.m. on Radio Nacional. (In June the first-grade lessons were rescheduled to 9:00 a.m. because of conflicts with programs sponsored by the Nicaraguan government.) Project lessons are being used by classrooms in the Departments of Masaya, Granada, and Carazo. The experimental area was expanded to increase the number of schools from which to draw classes and to accommodate some of the teachers in neighboring areas who expressed interest in working with the project.

Operations in the schools are handled somewhat differently for first-grade and second-grade classes. Worksheets and teacher's guides for first grade are distributed once a month through the Inspector's Office in the local department, while teacher's guides for second grade are distributed weekly. In both cases, teachers are asked to pick up materials themselves. Except for the use of Radio Nacional rather than tape recorders for playing radio tapes, lessons for second grade are handled in much the same way as first-grade lessons were in 1975.

The project is working in 45 first-grade classrooms, of which 30 were selected at random from among rural and urban schools in the Departments of Masaya, Granada, and Carazo. The method of selection is described by Friend, Searle, Suppes, and Zanotti (1976). Lesson materials are produced at the project office; approximately 40,000 worksheets and 900 teacher's guides are distributed monthly. Two teacher-training sessions were held at the beginning of the school year. Additional sessions have not proved necessary, but memos are occasionally distributed to teachers and messages are delivered by radio. In five classes (not among those selected at random) the mathematics lesson is observed regularly, and a daily summary of observations is prepared. Six classrooms are tested each week (this testing program is described below).

With the 30 experimental first-grade classrooms, the project is attempting to maintain greater distance between staff members and teachers,

as might be expected with a more wide-scale use of the program. These classrooms are not observed regularly and are not directly supervised by the project. Classrooms in Nicaragua are not often visited by school supervisors and it is important to find ways to oversee the program use that are feasible in the Nicaraguan setting. This year, teachers are asked to return special worksheets to the local school inspector's office once a month when they pick up lesson materials. The worksheets accompany a lesson that contains a test. The teachers are reminded of the test (by radio) the preceding day, and they are encouraged, by the teacher's guide, to grade the test and use the results to examine student progress.

Because the project needs information about the use of the program in first-grade classrooms, staff members visit experimental schools about once a month on a random schedule. The visits are unannounced and their sole purpose is to find out if the teacher is using the radio lesson on the day of the visit. The staff member need not enter the classroom nor disclose the true purpose of his visit, and the visits are not designed to encourage use of project lessons, only to gather information.

Twenty second-grade classes in the Department of Masaya were chosen for experimental work. Many other teachers in all three participating departments asked to be included in the program. Twenty of these teachers, who were in schools where other classes were using project lessons (at either grade level), were accommodated. The project supplies radios and teacher's guides for all 40 teachers. In 38 schools the radios are shared with first-grade classrooms. Five second-grade classrooms are observed at least twice a week, the remaining classrooms only occasionally. As with the first grade, a daily summary of observations is prepared. Two teacher-training sessions were held at the beginning of the school year, none subsequently.

Second-grade lessons are being produced without student worksheets and, therefore, the corresponding teacher's guides are longer than those for first grade. They contain all of the student exercises, printed in the guide in the form the teachers are asked to write them on the blackboard. Supplements to the guide are also distributed. These contain the words to songs and other general material.

Thus far this year, the project staff has maintained a schedule of preparing and broadcasting a lesson each day at each grade level. However, there have been many transmission difficulties that have resulted in much lost instructional time, and some confusion about the lessons. During the period from March 11 to May 26 there were 21 incidents of errors or disruptions, affecting both grade levels equally. The loss of instructional time varied from one to thirty minutes and several of the errors affected the teacher announcements. Several steps were taken to rectify these errors. A staff member was assigned to be at the recording studio each morning to personally deliver the correct tape and see that the announcements were read at the proper time. As mentioned above, the broadcast time was changed for first-

grade lessons, to avoid interruption by political broadcasts. And finally, routine announcements (e.g., the date of the next lesson) were added to the lesson tape although this means that a change must be made in each lesson tape before it can be used again.

C. Use of Feedback

Before discussing the work of the project in this area it is appropriate to make some general remarks about the use of observation and performance data (feedback) in lesson development. Two components of the lessons are affected by feedback, curriculum content and lesson format. The curriculum content of a lesson is unique and the appropriateness of the content of each lesson must be judged anew. Lesson format, on the other hand, includes those factors that are not specific to items of content. Among these are (a) the length of the lesson, (b) the length of individual segments, (c) the length of pauses allowed for student responses, (d) the types of entertainment used, (e) pacing, and (f) the language used for giving directions and for providing instruction. Information obtained about these aspects of lesson format is general and it can be used to improve lessons other than those for which the data were collected. The effect of this type of information on lesson development is cumulative. That is, lesson developers who regularly collect and use information about these aspects of the lessons will increase their knowledge of the target population and of the available options for formatting lessons and the quality of the lessons they produce will continually improve. Nevertheless, when lessons are being produced for successive primary-school grades, such observations can never be abandoned because the target population changes continually.

Classroom observations are the most useful source of information about aspects of lesson format and during 1976 the project has continued to collect such information, using much the same methods as during 1975. Numerical ratings are no longer used. Each day when observers return to the office a short session is held, led by the person who will write the summary. The observation forms are reviewed briefly and points of confusion or disagreement are discussed immediately. The summary is prepared shortly thereafter.

Methods for assessing the appropriateness of curriculum content have become much more systematic this year. Changes have been made in both the method for collecting performance data and in the method for designing curriculum. The changes in data collection have been implemented for both first and second grade, the changes in curriculum design for second grade only.

As reported earlier, paper-and-pencil tests are being used to collect performance data. At each grade level 18 classrooms form the pool to be tested and each week a test is administered in 6 of these classrooms. The classes are used on a rotating basis so that each is tested on the average 11 times during the 33-week school year. Three

test forms of about 12 items are used and each item is administered in two classrooms. Information is obtained on about 36 items each week. Item selection is a part of the curriculum development scheme that is described in the following paragraphs. All tests are given by project staff members at a time that does not interrupt the regular mathematics lesson.

The curriculum structure used for second grade was described earlier (see Section II.A). The curriculum is described by 273 classes of exercises and the position of each of these classes relative to the others is completely specified. Certain of these classes of exercises are identified as being key prerequisite classes. Students must perform at an acceptable level on these types of exercises before certain new material is introduced. For example, all two-addend two-column addition exercises without a carry form a class. This class is prerequisite to the class of two-addend two-column addition exercises with a carry in the units column. Children must know how to find sums without carrying before carrying is introduced. Hence, the first class is a key prerequisite for the second and is identified as such on the master curriculum plan.

According to the curriculum development scheme followed this year, each key prerequisite class is tested and the successor exercise class is taught only if performance is adequate. (If it is not, the key prerequisite class is retaught.) This means that the master curriculum plan must specify a sufficient time period between the prerequisite class and its successor so that the curriculum can be changed in response to the test results. It takes five weeks to produce a lesson (from the construction of the lesson outline to the delivery of teacher's guides to the classroom), so this is the time period shown in the master plan between each key prerequisite class and its successor. Only a small number of classes are key prerequisites to other classes. For example, of the 33 classes in the vertical addition strand, only four are key prerequisites.

In order to more accurately assess the effect of teaching, student performance on key prerequisite classes is assessed both before and after teaching. Maintenance of these crucial skills is examined by test items subsequent to teaching. The full testing plan assesses performance on 70 classes of exercises before teaching and at selected times after teaching.

The advantage of the scheme for using test data to determine curriculum development is that misjudgments can be corrected during the development of the instructional program. If a topic is taught poorly the children do not learn it, and without some method for tying curriculum development to student performance the error is not rectified. The earlier in the year deficient lessons occur, the less successful the teaching program is likely to be. Such errors can be corrected in a later revision (if they are discovered by appropriate testing), but it is impossible to predict the effect of the correction on the later parts of the program, so that equally serious errors can be made in the revised lessons, requiring yet another round of revisions.

Producing lessons with fast feedback (as we call this scheme) requires a tight production schedule, because each lesson must be written and recorded at the latest possible moment. Our contingency plan in case the schedule is not met, i.e., playing an earlier lesson, has not yet had to be invoked, but meeting the schedule has placed a heavy demand on the production staff.

D. Pretesting Program

At the beginning of the 1976 school year, pretests were administered at four grade levels. This testing program is summarized in Table 4. The TOBE, described earlier, was again used as a pretest

Table 4

Pretesting Program for 1976

Grade	Group tested	Selection method	Number of classes Masaya	Granada	Carazo
1	radio	random	10	10	10
1	traditional	random	8	8	8
2	radio	volunteer	20	—	—
2	traditional	random	8	8	8
3	traditional	random	8	8	8
4	traditional	volunteer	4	4	4

for first grade. All of the remaining tests were developed by the project staff. Traditional classes at the second-grade and third-grade levels were tested to provide control data for later comparisons. Because project lessons are broadcast on the national radio system and can be used by any teacher who has access to the teacher's guides, it will be increasingly difficult to obtain uncontaminated control data. Therefore, it seemed prudent to test classes in advance of the use of radio lessons. Unfortunately, second-grade classes were not tested at the beginning of the 1975 school year. The data for traditional classes obtained in 1976 will have to serve for the summative evaluation of 1977. Fourth-grade classes were tested to provide information for the development of curriculum for third grade, which is anticipated to take place in 1977. Although preliminary analyses of the test results are completed, these will be reported in

a later publication, when comparisons can be made between subgroups and between pretest and posttest results.

E. Working with Nicaraguan Educators

Initial arrangements for the 1976 experimental year were made in late 1975 when the project staff described the plans for the year to the Minister of Education and asked his permission to extend the work of the project to the Department of Carazo. The Minister approved the plans and asked the Director of Primary Education to cooperate with the project. The Director agreed to send a representative to a meeting at the project offices, held on January 13, which was also attended by the school inspectors from the three participating departments. The departmental inspectors gave permission to the project to make contact with the Directors of the schools with which the project wanted to work. Between February 5 and February 9 meetings were held with the 41 Directors of the selected schools. Finally, on February 11 and 12, the first teacher-training sessions were held, one for each department. The second set of teacher-training sessions were held between March 3 and March 8. Each teacher attended two sessions, each approximately three hours long.

III. MODEL FOR THE ALLOCATION OF REVIEW EXERCISES

It is accepted by a great many people that curriculum designers and writers should make explicit the curriculum objectives that are being served by the materials presented to students. Nevertheless, it is not well understood how lessons should be organized so that student performance will meet the objectives set by the curriculum designers. The model presented here provides specific quantitative results concerning the allocation of mathematics exercises to project lessons. The goal of the procedure is to maximize the mean student score (weighted as we describe below) on a year-end test of the objectives by manipulating the amount of practice provided on each topic. We first present a general discussion of the model and then describe its implementation using the 1976 second-grade curriculum.

The model assumes a curriculum that can be described by objectives that explicitly define a set of exercise types. The allocation or optimization problem we are confronted with has the following components. First, there is the number s of objectives. Second, there is the weight r_i assigned to each objective with the obvious constraints that $r_i \geq 0$ and $\Sigma r_i = 1$. Third, there is the initial probability of a correct response to an exercise in a given block of exercises. This initial probability of a correct response we shall denote by p_i or occasionally, when an indication of trial is needed, $p_{i,1}$. Correspondingly, we shall use the standard notation for the probability of an error, q_i and $q_{i,1}$, with $q_i = 1 - p_i$. Fourth, there is the mean learning rate a_i for each objective. Fifth, there is the mean forgetting rate b_i for each objective. Sixth, there is the number N of exercises in a given block, with N_i to be allocated to the ith objective. Our formal problem is to allocate the N_i exercises to each objective, with with $\Sigma N_i = N$, in such a way as to optimize performance at the end of the block. The measure of optimization is the weighted expected mean error rate, and thus we want to minimize the weighted expectation of the mean probability of an error.

There are, of course, a very large number of ways of allocating exercises, but we shall restrict ourselves to a periodic pattern as a

first approximation. Thus, an exercise relevant to objective i is offered on a given trial followed by k trials dealing with other objectives. This pattern of $k + 1$ trials is repeated periodically throughout the block. Obviously, in actually writing curriculum, one would deviate from the exact $k + 1$ periodicity, but the effects of minor deviations will not be significant and by making this periodic assumption we are able to make explicit computations that otherwise are considerably more difficult. (Under further simplifying assumptions made below, the periodicity assumption is not important at all.)

The learning and forgetting assumptions themselves are mean assumptions. Within these mean or averaging assumptions, a variety of individual models can be fit, as is well known from the literature of mathematical learning theory. In particular, the models of individual learning that can be accommodated to the mean learning assumptions may range from the all-or-none model, on the one hand, to the linear incremental model, on the other. The two mean equations are the following.

(1) Learning: $q_{i,n+1} = a_i q_{i,n}$

(2) Forgetting: $p_{i,n+1} = b_i p_{i,n}$

We can write the recursion for forgetting in terms of the probability of an error.

(3) $$q_{i,n+1} = b_i q_{i,n} + (1 - b_i)$$

After 1 learning trial and k forgetting trials, which constitutes a cycle of $k + 1$ trials, we can easily show the following.

(4)
$$q_{i,n+k} = 1 - (1 - q^{k}_{i,n})b_i$$
$$= b^{k}_{i} a_i q_{i,n} + (1 - b^{k}_{i})$$

The derivation of this result and others that closely follow are to be found in Suppes (1964).

After m_i cycles of $k_i + 1$ trials we can show that we have the following.

$$(5) \qquad E(q_{i,n+m_i k_i+m_i}) = b_i^{m_i k_i} a_i^{m_i} q_{i,n} + \frac{(1 - b_i^{k_i})(1 - a_i^{m_i} b_i^{m_i k_i})}{1 - a_i b_i^{k_i}}$$

As noted above, N is the total number of trials in a block. Since, under the assumptions made here, forgetting occurs on all trials that are not learning trials, the following simple relation holds between N, m_i, and k_i.

$$(6) \qquad N = m_i k_i + m_i$$

It should be noted that this equation holds for every objective i, with of course the following constraint.

$$(7) \qquad N = \Sigma m_i$$

Finally, to obtain the weighted expectation of q (the probability of an error) at the end of a block we obtain the following equation from Equations (5), (6), and (7).

$$(8) \qquad E(q) = \Sigma r_i \left| b_i^{N-m_i} a_i^{m_i} q_i + \frac{(1 - b_i^{k_i})(1 - a_i^{m_i} b_i^{N-m_i})}{1 - a_i b_i^{k_i}} \right|$$

As it stands, Equation (8) is rather difficult to work with in terms of finding an optimal solution that is the allocation of the learning trials N_i so as to minimize the expected error. Numerically, a good deal can be done in a straightforward way.

On the other hand, by making the overly strong simplifying assumption that there is no forgetting, that is, that $b = 1$, we can get an explicit solution of the allocation problem which will give us a first approximation that in many cases will also be a useful one. Thus we want to minimize

$$(9) \qquad E(q) = \Sigma r_i q_i a_i^{m_i},$$

subject to the constraint that $\Sigma m_i = N$. We use Lagrange multipliers to find a solution (where z replaces the standard lambda). Our basic function is

$$f(x_1,\ldots,x_M) = r_i q_i a_i^{m_i} + z(\Sigma m_i - N) .$$

Thus, taking derivatives we have:

$$(10) \qquad r_i q_i a_i^{m_i} \ln a_i + z = 0 ,$$

with

$$\Sigma m_i - N = 0$$

$$m_i > 0 .$$

Summing the M equations in z, we then obtain

$$(11) \qquad r_i q_i a_i^{m_i} \ln a_i = \frac{1}{M} \Sigma r_i q_i a_i^{m_i} \ln a_i ,$$

but the right-hand side of (11) is independent of i, and so we conclude that the condition for optimal allocation is the simple qualitative condition of equality that for every i and j

$$(12) \qquad r_i q_i a_i^{m_i} \ln a_i = r_j q_j a_j^{m_j} \ln a_j .$$

Equation (12) generalizes naturally with the equality condition holding, but the explicit expressions are quite complex.

We have applied this model to help organize the second-grade curriculum, which has 30 global objectives, G (which elsewhere we have called strands). The G_i are divided into 273 subobjectives, G_{ij} (which we have also called classes of exercises). Two hundred fifty exercises are allocated each week to the appropriate subobjectives. Some of these exercises are for initial instruction, and the remainder are for practice, to maintain the skill or concept taught. We assume that for each subobjective, G_{ij}, the first E_{ij} exercises provide

instruction. These exercises are presented in a concentrated period of time, lasting no more than three weeks. Thereafter, maintenance exercises are presented periodically.

The following parameters are associated with each G_{ij}:

1. q_{ij}, the error rate for G_{ij} immediately prior to the initiation of instruction,

2. t_{ij}, the week in which instruction starts, and t^*_{ij}, the number of weeks of instruction,

3. E_{ij}, the total number of instructional exercises,

4. t^*_{ij} ordered pairs, (t^k_{ij}, e^k_{ij}), where $k = 1,\ldots t^*$, and $\Sigma e^k = E$,

5. the weight r_{ij}, a normative measure of importance,

6. a_{ij}, the learning parameter, and

7. b_{ij}, the forgetting parameter.

Three parameters, t, the week in which instruction starts, t^*, the number of weeks of instruction, and E, the total number of instructional exercises, were determined by the curriculum designer. We had no data for estimation of the error rate or the learning parameter for each subobjective. Therefore, for the initial implementation of the model, the curriculum designers made estimates, for each subobjective, of the probability correct before and after teaching. These estimates, together with the number of exercises used for teaching, allowed the use of equation (1) for calculating the learning parameter for each subobjective.

The weight r associated with each subobjective reflects the 'importance' of a high performance level on the objective at the end of the school year. The weights were estimated by the curriculum designers. We assume for r the following properties: (a) r remains constant during the school year, and (b) the value of r is independent of the time that the subobjective is first taught. The weight is used in computing the predicted score on the year-end examination.

The model has been used to construct a computer program that computes m_{ij}, the number of exercises allocated to each subobjective by choosing, at each step, the exercise that gives the maximum increase in the year-end test score.

IV. COST ANALYSES

A preliminary assessment of the costs of radio instruction in Nicaragua was carried out by Dr. Dean Jamison, an educational economist now at the World Bank. The full analysis is published in the project's Second Annual Report (Searle, Friend, & Suppes, 1975). Jamison allocated costs to four categories: central project, program preparation, transmission, and reception site. The cost estimates for the reception site were quite high--probably too high for the Nicaraguan government to be able to implement the program. These estimates are reproduced in Table 5, which was condensed from a revised version of Jamison's paper (Jamison, 1976).

During 1976 the project has tried to change the program to reduce reception costs. First, second-grade lessons are being developed without student worksheets, and, if this effort is successful, the first-grade curriculum will be rewritten to similarly eliminate worksheets. Second, school visits have been eliminated as a method for supervising teachers. Two other methods are being tested this year, the collection of student tests and communication with teachers by radio and by printed memo.

Reception costs can also be reduced by decreasing the amount of teacher training. Only two sessions have been held thus far in 1976, as compared with eight sessions during 1975. Furthermore, teachers are being asked to share radios--this year 56 radios provide lessons in 95 classrooms. Finally, the instructional program has been increased to 165 lessons per year.

Jamison's estimated reception cost for 150 lessons a year was $3.83 per student. Table 6 presents estimated reception costs assuming the implementation of the following changes: Schools are visited only once a year, two radios are shared between three classrooms, teacher training is reduced to six hours a year, worksheets are eliminated, the teacher's guide is increased to 400 pages a year, and the amount spent on miscellaneous supplies is increased to 60 cents a year. With these changes, the reception cost per student per year drops to $1.90, a 50% reduction.

Preliminary cost estimates have been made for several aspects of the project's field activities and these are reported here. Only direct costs are given, and administrative costs that can be attributed to each activity have not been included.

The total cost for the classroom observation program during 1976 will be about $21,450. Costs for individual components are shown in Table 7. Three first-grade and three second-grade classes are visited each day. On the average, one of these visits is by a Stanford staff member, five by Nicaraguan staff members. A visit

Table 5

Reception Site Costs (150 Lessons)[a]

Cost category and description	Unit cost	Total
Costs common to school		$78.00
Supervision (6 visits per year) Cost per visit	$13.00	
Costs common to classroom		38.00
Radio set (annual cost)	12.00	
Batteries	5.00	
Teacher's guide (100 pages)	1.00	
Teacher training (10 hours/year)	20.00	
Costs individual to student		2.00
Blank paper (40 pages/year)	.10	
Worksheets (150 pages/year)	1.50	
Miscellaneous supplies	.40	
Per-student reception cost per year		3.85[b]

[a] Condensation of Table 5 of Jamison, 1976, p. 12.

[b] Assumes three participating classrooms per school and 35 students per classroom.

takes approximately two hours, one in the classroom and one for transportation. Preparation of the observation sheets before the lesson and of the summaries after the lesson takes about one man-day. These tasks are done by Nicaraguan professional staff members. Typing and mimeographing are the responsibility of the support staff.

Table 6

Revised Estimated Reception Site Costs (165 Lessons)

Cost category and description	Unit cost	Total
Costs common to school		$13.00
Supervision (1 visit per year) Cost per visit	$13.00	
Costs common to classroom		27.33
Radio set (annual cost)	8.00	
Batteries	3.33	
Teacher's guide (400 pages)	4.00	
Teacher training (6 hours/year)	12.00	
Costs individual to student		1.00
Blank paper (160 pages/year)	.40	
Miscellaneous supplies	.60	
Per-student reception cost per year		1.90[a]

[a] Assumes three participating classrooms per school and 35 students per classroom.

The administration of weekly tests will cost about $11,900 this year. The first tests were given in the fifth week of the school year and they will continue until the 33rd week. Twelve tests are given each week. The breakdown for weekly costs, shown in Table 8, includes the duplication, administration, and correction of tests, but not the cost of item preparation.

The costs for the pretesting program cover test duplication, the recording of instructions, and the classroom administration of tests. Neither item preparation nor data analysis are included.

Table 7

Classroom Observation Costs for Two Grades per Day

Stanford staff	$ 42
Nicaraguan professional staff	50
Nicaraguan support staff	30
Materials	3
Transportation	5
Total daily cost	$130
TOTAL YEARLY COST	$21,450

Table 8

Cost of Administration of Weekly Tests Two Grades per Week

Stanford staff	$225
Nicaraguan professional staff	120
Nicaraguan support staff	60
Materials	5
Transportation	15
Total weekly cost	$425
TOTAL YEARLY COST	$11,900

A breakdown of the cost for testing 134 classrooms is shown in Table 9. The testing program occupied a total of 8 man-days for Stanford staff members, 67 man-days for Nicaraguan staff members, and 36 man-days for the support staff. The cost for materials includes the purchase of 1,620 TOBE test booklets.

Table 9

Pretest Administration Costs

Stanford staff	$1,000
Nicaraguan professional staff	1,340
Nicaraguan support staff	540
Materials	491
Transportation	360
Recording	300
TOTAL COST	$4,031

At the end of the 1974 school year, at the beginning and end of the 1975 school year, and again at the beginning of the 1976 school year, teachers were asked to respond to a questionnaire. The field work associated with this effort has cost approximately $9,165 thus far. The interviews conducted at the end of the 1975 school year had an estimated cost of $3,160. During the period from June 1974 to the present the project has been collecting data for the dropout and repetition study described in the next section. The cost to date for this effort is estimated at $4,275. Finally, the classroom observation study, described later in this report, has cost about $13,140.

V. OTHER RESEARCH ACTIVITIES

A. Dropout and Repetition Study

Both dropout and repetition rates are very high in the primary schools of Nicaragua--a common finding in many developing countries. Since June 1974 the project has been collecting data that should help elucidate the problems of dropout and repetition and perhaps lead to some hypotheses about their causes. We present here only a summary of some of the basic data collected for 1974 first-grade students. Further data collection is in progress, and the full data base, for two school years, will be the subject of an extensive analysis by Dr. Dean Jamison and Dr. Kathleen McNally, consultants to the project.

At the end of 1974 the teachers of the 44 first-grade classes that were given the year-end achievement test (Searle, Friend, and Suppes (in press) were asked to submit the following information about students in their classes: sex, age, distance walked to school, parents' occupation, attendance by month, number of times first grade had been repeated, and several items about year-end performance. At the beginning of the following school year (February 1975), further information on the return of the children to school was obtained. At least partial information was obtained for 1,735 children.

Monthly attendance was reported for 1,456 children. Some students showed the following attendance pattern: Starting with some school month, attendance reporting ceases. For example, a student may have attendance reported for February, March, May, and June, but not thereafter. There are 222 children who exhibited this attendance pattern and they will be referred to here as <u>dropouts</u>. The remaining children for whom attendance data are reported will form the <u>regular</u> group. No attempt has been made to verify the attendance reports and, therefore the label <u>dropout</u>, for individual children.

Table 10 presents a summary of the attendance data. The percentage of dropouts (as defined above) increases during the first five months of school, reaching 1.9 in July. Thereafter, it remains at roughly 2%. Of the 1,456 children, 10.8 are classified as dropouts. The table also shows the percentage of children for whom there is no reported attendance for the indicated month but for whom attendance is reported in some later month. The higher percentage for the first month (7.1%) apparently reflects late enrollment. Thereafter, the figure remains below 3%. The absence of attendance data can occur either because the child did not attend school or because the teacher failed to report the attendance for that month.

It is clear from an examination of Table 10 that there are errors in the data. For April and August the maximum number of days attended was 29 and 28, respectively, more than the total number of

Table 10

Attendance of First-grade Students by Month for 1974

Month	Percentage Dropout	Percentage Missing data	Number of Days in Attendance Max	Mode	Median	Mean	SD
Feb	---	7.1	20	14	14	2.6	2.47
Mar	.2	2.8	22	20	18	16.9	4.28
Apr	.5	2.0	29	15	14	12.7	3.33
May	1.0	1.4	23	20	18	16.5	4.48
Jun	1.7	1.3	21	20	18	16.3	4.39
Jul	1.9	2.7	23	16	15	14.0	3.93
Aug	1.8	.8	28	22	20	17.8	4.78
Sep	1.9	.8	22	18	16	15.3	4.28
Oct	1.8	.7	23	23	20	18.1	4.94
Nov	2.0	---	18	11	11	10.8	3.51
Total	10.8		198	156	173	139	43.2

Dropout: Student with no attendance for current month and all following months.

school days in the month. (The frequency of such identifiable errors is low.) The mode, median, and mean attendance figures are presented for each month. Without exception, the mode is the greatest of the three values, followed by the median, and then the mean. Thus, the usual value for attendance is close to the maximum and the values close to this are the most frequent, while values below the median are much lower. it appears that most of the children who remain in school attend regularly.

Several comparisons were made between the dropout and the regular groups. Table 11 shows the percentages of boys and girls in each group. The age distribution for both groups is shown in Table 12, and Table 13 gives the distance walked to school. In comparison with

Table 11

Sex of First-grade Students in Regular and Dropout Groups

	Total		Regular		Dropout	
Sex	N	%	N	%	N	%
Boys	927	53.4	644	52.2	112	50.5
Girls	808	46.6	589	47.8	110	49.5

Table 12

Age Distribution of First-grade Students in Regular and Dropout Groups

	Percentage of Students		
Age	Total	Regular	Dropout
under 7	5.4	5.0	6.4
7	22.1	23.2	20.8
8	29.2	29.7	27.1
9	16.5	15.8	16.7
10	11.8	12.3	8.1
11	6.9	6.8	8.6
12	4.8	4.6	4.5
over 12	3.3	2.5	7.7

the regular group, the dropout group has more girls, more students over eight years old, and more students living far from school, but all of these differences are small.

The number of times that first grade was repeated is shown in Table 14. Seventy-three percent of the dropout group is in first grade for the first time, as compared with 61% of the regular group.

Table 13

Distribution of Distance Walked to School for First-grade Students in Regular and Dropout Groups

Meters from school	Percentage of Students Total	Regular	Dropout
0-100	13.8	13.8	13.9
101-500	48.7	50.9	45.0
501-1500	29.4	27.7	33.5
1501-8000	8.2	7.6	7.7

Table 14

Number of Repetitions of First Grade for Students in Regular and Dropout Groups

Years repeated	Percentage of Students Total	Regular	Dropout
0	64.6	60.8	73.0
1	22.2	24.5	15.3
2	11.9	13.1	9.9
3	1.3	1.5	1.8
4	0.1	0.1	0.0

Thus, it does not appear to be true that students who have failed previously are more likely to drop out of school.

Much additional work remains to be done with this data base. The reenrollment data will be studied and the relationship of dropout and repetition to student performance data will be examined. Further

comparisons will be made between the dropout and regular groups and students in rural, municipal, and urban schools. Finally, these data will be studied from the point of view of the flow of students through the educational system and from an economic standpoint.

B. Classroom Observation Study

The classroom observation study is designed to examine the impact of the radio instructional system on the events that take place in the classroom. Some of the specific events of interest are the following:

1. The use of visual and concrete materials.
2. The amount of time spent on mathematics compared to organization, discipline, etc.
3. The opportunities the children have for active participation.
4. The use of immediate feedback.
5. The use of positive reinforcement.
6. The amount of interaction of the teacher with children of different sex and in different ability groups,
7. Ways in which teachers participate during the radio broadcast.

Six teachers are participating in the study, with three sets of classroom observations collected from the classes of each of the teachers. (The six teachers are volunteers from the Department of Masaya.) The first set of data was collected at the end of the 1974 school year, before any of the teachers had been introduced to the radio lessons. The second set of data was collected during the early part of the 1975 school year, shortly after the teachers had started using the radio programs. The final set of data was collected at the end of the 1975 school year. Thus, the three sets of data make up the following treatment conditions: pre-radio, early radio, and late radio.

Data on what took place in the classroom were collected by means of a portable stereo tape recorder. One channel of the recorder was used to record the public verbal interchanges that occurred, using a single omnidirectional microphone placed in the center of the classroom. The second channel was used to record the comments of an observer, a project staff member. The observer dictated into the recorder the important nonverbal characteristics of the lesson, such as the kind of visual or concrete materials being used, the sex and ability group of each child who spoke or was being spoken to, the grouping pattern of the class, information written on the chalkboard and all nonverbal forms of teacher feedback, such as correcting children's notebooks.

Trained staff members are now coding the tapes made in the classrooms. The coding instrument, which has three parts, was designed specifically for this study. Part A provides information about the structure of the class, such as the lesson format, grouping structure,

and use of materials. Part B provides details about the verbal and nonverbal communications--who says what to whom. Part C provides data on the frequency of important, but rarely occurring, events, such as intellectualizing, teaching mathematical terminology, and the occurrence of mathematical errors.

The preliminary data analysis, which is now under way, will look at the data from two different perspectives. First, the occurrence of the various activities in the classroom will be measured. For example, the analysis will show how much of the time children participate actively, or how often concrete materials are used, or how much of the content of the lesson is directly related to mathematics. The second perspective will examine the frequency of certain combinations of activities, for example, how often does the teacher say something to the children about mathematics when the children are working in groups as compared with when they are working alone.

A comparison will be made between the teachers at each time period, and for the teachers over the three time periods. In addition, for the radio classes, comparisons will be made between the radio and nonradio parts of the classes.

VI. WORK PLAN FOR 1976-1977

The final contract year includes the second half of the 1976 school year and the first half of the 1977 school year. For the remainder of the present school year the project will continue lesson presentation in first and second grade. Both instructional programs will contain 165 lessons, each with a radio portion and a postbroadcast portion. The evaluation of first-grade lessons will be completed by posttesting in experimental and traditional classrooms. The plans for the evaluation are described in detail in Friend, Searle, Suppes, and Zanotti (1976). Participating teachers will complete a questionnaire at the end of the school year and the project advisory committees will review the work of the year.

During the first week of September the project will sponsor an international conference in Nicaragua for representatives of educational radio projects in developing countries. Approximately 15 experts in the field of lesson development and production will work with the project to review its methods and results.

In November two staff members will attend a seminar in Rio de Janeiro sponsored by PRONTEL (Programa Nacional de Teleducacao). The subject of the seminar is to be Radio Mathematics and the participants will include representatives from five Brazilian state programs directly concerned with teaching mathematics by radio. The purpose of the meeting is to provide an opportunity for the project to share its experiences with its Brazilian counterparts.

At present, plans for 1976 are predicated on the assumption that the project will continue to work in Nicaragua beyond the present funding period. (If the work of the project is not to be continued, the Stanford staff members will leave Nicaragua at the end of 1976 and return to Stanford for the remainder of the contract period.) Although the work plan for 1977 is not yet firm, it is likely that the project will develop lessons for the third grade. (The alternative is to completely revise the first-grade lessons so that they do not depend on the use of student worksheets.) The decision has not yet been made whether the present first-grade lessons will be broadcast during 1977. Lessons for the second grade and third grade will be broadcast to the three departments that presently receive project lessons. The effectiveness of second-grade lessons will be evaluated using experimental classrooms selected at random, and performance of students in radio classes will be compared with that of students in traditional classrooms.

In developing lessons during 1977, the project plans to use the tight feedback loop described in Section II.C of this report and the model for the allocation of review exercises described in Section III. Both of these procedures, under development during 1976,

are tools for using information about the performance of students to increase the effectiveness of lessons. These new methods for curriculum development are not described in the annual report for 1974-1975. They have grown out of the work for this year, and will be further tested during the next. We hope, in a year's time, to report on the development of other, unanticipated contributions to the development of the effective use of radio for instruction.

VII. DISSEMINATION AND UTILIZATION OF RESEARCH RESULTS

During the year, the project publicized its work though attendance of staff members at international and national meetings and through correspondence. Mrs. Friend and Mrs. Vrooman attended the International Conference on the Use of Satellites for the Transmission of Educational Programs in Mexico City, September 2-11, 1975. Mrs. Friend also visited the Basic Village Education Project in Guatemala. Dr. Searle submitted a paper to and participated in the International Conference on Evaluation and Research in Educational Broadcasting, April 5-9, 1976, sponsored by the Open University of Britain. In the United States, Dr. Searle presented papers a' Educational Testing Service and the Annual Meeting of the National Council for Teachers of Mathematics, and attended the meeting on Education for Radio and Development sponsored by the Institute for Communications Research at Stanford. She also visited the Radio Software Research Project at the University of Massachusetts at Amherst and the Basic Village Education Project in Guatemala.

Dr. Jamison, consultant for the project, submitted a paper on a preliminary cost analysis of the project to the International Conference on Evaluation and Research in Educational Broadcasting and participated in the conference. Dr. McNally presented a paper at the Econometric Society in Dallas. Dr. Shirley Hill, Associate Professor of Mathematics Education at the University of Missouri spent part of her sabbatical year working with the project, both in Nicaragua and at Stanford.

The project mailing list now contains the names of 72 people from 24 countries, almost all of whom are known to at least one member of the project staff. The distribution of these people among countries is as follows:

Brazil	6	Mexico	6
Canada	1	Nepal	1
Chile	1	Nigeria	3
Colombia	5	Pakistan	1
Ecuador	2	Panama	3
England	2	Paraguay	2
Ethiopia	1	Peru	3
France	2	Philippines	3
Haiti	1	Swaziland	2
Indonesia	1	Thailand	3
Iran	1	U.S.A.	9
Korea	1	Vietnam	2

Approximately 50 people have written asking for information about the project, about half of them from other countries. The countries represented, in addition to those listed above, include Costa Rica, India, and Israel.

The project staff has had preliminary discussions concerning the use of lessons with a professor from the University of Jalapa in Mexico and from a school district in Houston, Texas, with a large Spanish-speaking population. Mrs. Marian Beard of the Institute staff discussed the project lessons and their possible use with an Eskimo population in a visit to Barrow, Alaska.

As an aid in disseminating its findings, the project staff has written a book about the work of the first experimental year. The book, which will appear in the next few months, is published by the Institute and will be distributed to libraries, related projects, and all those on the project mailing list. A full list of the papers and publications developed during the year is given below.

Books

Searle, B., Friend, J., & Suppes, P. The Radio Mathematics Project: Nicaragua, 1974-1975. Stanford, Calif.: Stanford University, Institute for Mathematical Studies in the Social Sciences, in press.

Articles

Jamison, D. The cost of instructional radio in Nicaragua: An early assessment. Proceedings of International Conference on Evaluation and Research in Educational Broadcasting. Milton Keynes, England: Open University, Institute of Educational Technology, 1976.

Searle, B., & Suppes, P. The Nicaraguan radio mathematics project. Educational Broadcasting International, 1975, 8, 117-120.

Searle, B., & Suppes, P. The Nicaraguan radio mathematics project. The Mathematics Teacher (Indian edition), in press.

Searle, B., & Suppes, P. The Nicaraguan radio mathematics project. In Proceedings, International Conference on Evaluation and Research in Educational Broadcasting. In press.

Searle, B., Suppes, P., & Friend, J. The Nicaraguan radio mathematics project. In D. Jamison, E. McAnany, & P. Spain (Eds.), Radio for education and development. World Bank, in press.

Suppes, P., & Searle, B. Survey of the instructional use of radio, television, and computers in the United States. Journal of the Society of Instrument and Control Engineers (Japanese edition), in press.

Papers

Jamison, D., & McNally, K. Factors influencing the demand for schooling in Nicaragua. Paper presented at the meeting of the Econometric Society, Dallas, December 1975.

Searle, B. Curriculum design for radio instruction. Paper presented at the Educational Testing Service, Princeton, September 1975.

Searle, B. Teaching mathematics by radio in Nicaragua. Paper presented at the annual meeting of the National Council of Teachers of Mathematics, Atlanta, April 1976.

VIII. INVOLVEMENT OF MINORITY PERSONNEL AND WOMEN

There are six professionals on the Stanford staff of the Radio Mathematics Project, three at the Institute for Mathematical Studies in the Social Sciences (IMSSS) at Stanford, and three in Nicaragua. Three of the six professionals are women and one is of Puerto Rican origin. The remaining staff members at Stanford are a programmer (male), a secretary (female), and a graduate student (male). IMSSS has, during its entire history, maintained a congenial atmosphere for both men and women of all types of backgrounds. That the Project Director in Nicaragua and the Project Coordinator at IMSSS are both women is not an unusual circumstance. Although the project has no plans for increasing the size of the staff, any replacements will be made within the policy guidelines for Stanford University that call for active recruiting of women and minority personnel.

IV. REFERENCES

Friend, J., Searle, B., Suppes, P., & Zanotti, M. Research plan, Radio Mathematics Project. Unpublished manuscript, Stanford University, Institute for Mathematical Studies in the Social Sciences, 1976.

Jamison, D. The cost of instructional radio in Nicaragua: An early assessment. Proceedings of International Conference on Evaluation and Research in Educational Broadcasting. Milton Keynes, England: Open University, Institute of Educational Technology, 1976.

Searle, B., Friend, J., & Suppes, P. The Radio Mathematics Project: Nicaragua, 1974-1975. Stanford, Calif.: Stanford University, Institute for Mathematical Studies in the Social Sciences, in press.

Searle, B., Friend, J., & Suppes, P. Application of radio to teaching elementary mathematics in a developing country (2nd annual report). Stanford, Calif.: Stanford University, Institute for Mathematical Studies in the Social Sciences, 1975.

Suppes, P. Problems of optimization in learning a list of simple items. In M. W. Shelly, II, & G. L. Bryan (Eds.), Human judgments and optimality. New York: Wiley, 1964. Pp. 116-126.

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NOTICE OF RESEARCH PROJECT

SUPPORTING ORGANIZATION:

Agency for International Development

SUPPORTING ORGANIZATION NUMBER(S):

Contract No: and/or Control No: AID/CM/ta-C-73-40

PROJECT TITLE:

Application of Radio to Teaching Mathematics in a Developing Country

INVESTIGATOR(S):

Patrick Suppes

DEPARTMENT/SPECIALTY, School or Division

Director
Institute for Mathematical Studies in the Social Sciences
Stanford University

PERFORMING ORGANIZATION:

Name and Address: Including Zip Code.
IMSSS, Ventura Hall
Stanford University
Stanford, Ca. 94305

PERIOD FOR THIS NRP:

Start Date: July 1, 1973
End Date: June 30, 1977
Annual Funding: $400,000

PROJECT SUMMARY: Be brief-200 word maximum: (Include Objective, Approach, Current Plans and/or Progress)

ABSTRACT

The Radio Mathematics Project was established to design, implement, and evaluate a prototype system of teaching elementary mathematics using radio as the major medium of instruction. The project, working in rural and urban primary schools in Nicaragua, presents daily mathematics lessons in first and second grade classrooms. A lesson has a radio and a postbroadcast portion, each about 30 minutes in length. Radio lessons are constructed from segments of instructional material and entertainment activities, both of which require a high level of active responses from the children. In its work thus far, the project has found (a) that first-grade children can learn new mathematical concepts and skills from instruction given by radio and supplemented by a student worksheet, (b) that children remain attentive and responsive for a half-hour radio lesson, provided they have the opportunity to respond frequently, and (c) children are able to respond at the high rate of three to four times a minute. The children enjoy the instructional segments of the project lessons. Although they provide a change of pace, the entertainment segments are not necessary for maintaining the children's attention. Test results indicate that children in radio classrooms perform better than children in traditional classrooms on all topics taught by the radio.